TECHNICAL MEMORANDUM

X-709

EFFECTS OF TWIN-VERTICAL-TAIL ARRANGEMENT ON THE AERODYNAMIC CHARACTERISTICS AT A MACH NUMBER OF 2.20 OF A MODEL OF AN 83.5° DELTA-WING AIRPLANE HAVING AUXILIARY VARIABLE-SWEEP WING PANELS

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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SUMMARY

An investigation has been conducted in the Langley 4- by 4-foot supersonic pressure tunnel at a Mach number of 2.20 to determine the aerodynamic characteristics of delta-wing configuration having variable-sweep wings. The investigation included tests with a single vertical tail and twin vertical tails in combination with twin ventral fins.

The results indicate that replacing the single vertical tail with a twin-tail arrangement extended the directional stability of the configuration with wings swept 83.5° from an angle of attack of about 12° to an angle of attack of greater than 17°. A decrease in area of the upper portion of the twin-tail arrangement caused a decrease in directional stability; however, the configuration remained directionally stable throughout the angle-of-attack range of the tests. The installation of forebody strakes to improve the directional stability of the wing-body configuration had little effect within the angle-of-attack range of the tests. Decrease in sweep of the wing panel of the configuration with the twin-tail arrangement from 83.5° to 15° resulted in a decrease in directional stability and effective dihedral throughout the test angle-of-attack range.

INTRODUCTION

The National Aeronautics and Space Administration is currently conducting studies directed toward the development of a multimission

*Title, Unclassified.

airplane wherein variable-sweep wings are used to combine subsonic and supersonic requirements necessary to perform long-range subsonic ferrying and supersonic flight at both high and low altitudes. Studies of various tail-aft configurations as well as several low-aspect-ratio delta-wing configurations have indicated directional-stability problems at moderate angles of attack in the supersonic speed range as a result of instability of the wing-body configuration and of the deterioration of the tail contribution with angle of attack. (For example, see refs. 1 to 4.) An attempt has been made to improve the directional stability of the delta-wing configuration reported in reference 4 by use of twin-vertical-tail arrangement located near the wing tips. The investigation was conducted in the Langley 4- by 4-foot supersonic pressure tunnel at a Mach number of 2.20.

SYMBOLS

All data presented herein are referred to the body-axis system except the lift and drag which are referred to the wind-axis system. The moment reference is at a longitudinal station corresponding to 63.2 percent of the body length.

b reference span, represented by width of model base; 10.55 in.

c reference chord, represented by length between body stations 13.18 and 37.68; 24.50 in.

C_D drag coefficient, $\frac{\text{Drag}}{qS}$

C_L lift coefficient, $\frac{\text{Lift}}{qS}$

C_l rolling-moment coefficient, $\frac{\text{Rolling moment}}{qSb}$

C_m pitching-moment coefficient, $\frac{\text{Pitching moment}}{qSc}$

C_n yawing-moment coefficient, $\frac{\text{Yawing moment}}{qSb}$

C_Y side-force coefficient, $\frac{\text{Side force}}{qS}$

C_{l_β} effective-dihedral parameter

C_{n_β} directional stability parameter

C_{Y_β} side-force parameter

q free-stream dynamic pressure

S reference area, represented by planform area (wings fully retracted) between body stations 13.18 and 37.68; 1.444 sq ft

α angle of attack, deg

β angle of sideslip, deg

Λ sweep angle of leading edge of outboard wing panel, deg

Tail component designations:

V_O original tail arrangement including vertical tail, ventral fins, and fairing tank

V_L lower component of modified twin-tail arrangement

V_U large upper component of modified twin-tail arrangement

V_u small upper component of modified twin-tail arrangement

MODEL

Details of the model with the single vertical tail are shown in figure 1; additional details of this model are found in reference 4. Details of modifications including body strakes and twin vertical tails in combination with twin ventral fins are shown in figure 2. Photographs of the model with the twin-tail arrangement are presented in figure 3. The modified vertical tails and ventral fins were designed so that the total area was equivalent to the sum of the areas of the vertical tail and ventral fins of the original configuration. The portion of the modified vertical tail above the wing-chord plane had an area equal to 55 percent of the total area of the tail arrangement, an aspect ratio of 1.1, and a taper ratio of 0.54. During the investigation the area of the modified vertical tail was decreased 10 percent by decreasing the span, with a resultant aspect ratio of 0.93. All tests were made with 0.10-inch-wide boundary-layer transition strips of No. 120

carborundum grains located 0.25 inch behind the fuselage nose, the duct-inlet lips, the vertical-tail leading edge, and the horizontal-tail leading edge. The model was mounted on a remotely controlled sting, and force measurements were made through the use of a six-component internal strain-gage balance.

TESTS, CORRECTIONS, ACCURACY

The test conditions were as follows:

Mach number	2.20
Stagnation pressure, lb/sq ft	720
Stagnation temperature, $^{\circ}F$	100
Reynolds number per foot	1.13×10^6

The stagnation dewpoint was maintained sufficiently low (-25° F or less) to insure that no condensation effects were encountered in the test section.

Tests were made through a range of sideslip angles from -4° to approximately 11° at angles of attack of about -4.3°, 0°, 4.3°, 8.5°, 12.8°, and 17.2°. The angles of attack and sideslip were corrected for deflection of the balance and sting under load. The base pressure was measured and the drag was adjusted to a base pressure equal to free-stream static pressure. The internal drag was determined from the change in momentum from free-stream conditions to conditions measured at the duct exit during previous tests of the model. The corrections for base drag and internal drag in coefficient form were approximately 0.0030 each.

The estimated accuracy of the measured quantities is as follows:

C_L	±0.0045
C_D	±0.0005
C_m	±0.0006
C_l	±0.0002
C_n	±0.0007
C_Y	±0.0023
α, deg	±0.10
β, deg	±0.10

RESULTS AND DISCUSSION

The lateral aerodynamic characteristics in sideslip for the original configuration are presented in figure 4 to give an indication of the linearity of the test results. Inasmuch as the linearity of the results of figure 4 is typical, subsequent sideslip results are presented in derivative form. Results presented in figure 5 indicate that the configuration with the original vertical tail and ventral fins was directionally stable at $\alpha = 0^{\circ}$ but that the stability deteriorated rapidly with increase in angle of attack until directional instability occurred at angles of attack beyond about 12°. Increasing the tail volume by shifting the tail rearward 5.5 percent of the body length caused a small increase in $C_{n_{\beta}}$ throughout the angle-of-attack range for which the model was directionally stable. (See fig. 6.) Replacement of the original vertical-tail arrangement with the modified twin-tail arrangement $\left(V_U \text{ and } V_L\right)$ resulted in positive directional stability throughout the angle-of-attack range and extended the range to $\alpha \approx 17^{\circ}$. (See fig. 7.) This improvement in $C_{n_{\beta}}$ is a result of two effects. First, the stabilizing increment at high angles of attack provided by the upper portion of the twin tails V_U increases because of favorable sidewash developed in the region of the tails. Second, the lower portion of the twin tails V_L provides a stabilizing increment in $C_{n_{\beta}}$ that remains essentially constant throughout the angle-of-attack range. The modified tail arrangement also provided a reduction in effective dihedral.

In an effort to reduce the deterioration of $C_{n_{\beta}}$ with angle of attack caused by the wing-body configuration, a small strake was attached to the forebody and was tested in conjunction with the modified tail arrangement. The results (fig. 8) indicate little effect of the strakes for the angle-of-attack range of the tests, although there is an indication that the strakes would provide some improvement in $C_{n_{\beta}}$ at still higher angles of attack.

In order to determine the amount by which the total surface area might be reduced while still maintaining directional stability, the area of the upper portion of the modified tail V_U was decreased 10 percent by decreasing the span. The results obtained with this smaller modified tail V_U indicate a nearly constant decrease in $C_{n_{\beta}}$ (fig. 9); however, the model remained directionally stable throughout the angle-of-attack range of the tests. A decrease in the wing sweep from 83.5° to 15° resulted in a decrease in directional stability and in the effective-dihedral parameter $\left(-C_{l_{\beta}}\right)$ throughout the angle-of-attack range. (See fig. 10.) Results presented in figure 11 indicate that the modified twin-tail arrangement had little effect on the longitudinal aerodynamic characteristics of the configuration with the wings fully retracted.

SUMMARY OF RESULTS

An investigation has been conducted at a Mach number of 2.20 to determine the aerodynamic characteristics of a delta-wing configuration having variable-sweep wings. The investigation included tests with a single vertical tail and twin vertical tails in combination with twin ventral fins. The following results were indicated:

1. The replacement of the single vertical tail with a twin-tail arrangement extended the directional stability of the configuration with wings swept 83.5° from an angle of attack of about 12° to an angle of attack of greater than 17°.

2. A decrease in area of the upper portion of the twin tail caused a decrease in directional stability; however, the configuration remained directionally stable throughout the angle-of-attack range of the tests.

3. Decrease in sweep of the wing panel of the configuration with the twin-tail arrangement from 83.5° to 15° resulted in a decrease in directional stability and effective dihedral throughout the test angle-of-attack range.

4. The use of forebody strakes to improve the directional stability of the wing-body configuration indicated little effect within the angle-of-attack range of the tests.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Station, Hampton, Va., June 14, 1962.

REFERENCES

1. Spearman, M. Leroy, and Foster, Gerald V.: Effects of Various Modifications on the Supersonic Stability Characteristics of a Variable-Wing-Sweep Configuration at a Mach Number of 2.01. NASA TM X-260, 1960.

2. Foster, Gerald V.: Stability and Control Characteristics at Mach Numbers of 2.50, 3.00, and 3.71 of a Variable-Wing-Sweep Configuration With Outboard Wing Panels Swept Back 75°. NASA TM X-267, 1960.

3. Foster, Gerald V.: Static Longitudinal and Lateral Aerodynamic Characteristics at a Mach Number of 2.20 of a Model of an 82° Delta-Wing Airplane Having Auxiliary Variable-Sweep Wing Panels. NASA TM X-707, 1963.

4. Spearman, M. Leroy: Static Longitudinal and Lateral Aerodynamic Characteristics at Mach Numbers of 1.41 and 2.20 of a Model of a Low-Aspect-Ratio 83.5° Delta-Wing Airplane Having Auxiliary Variable-Sweep Wing Panels. NASA TM X-708, 1963.

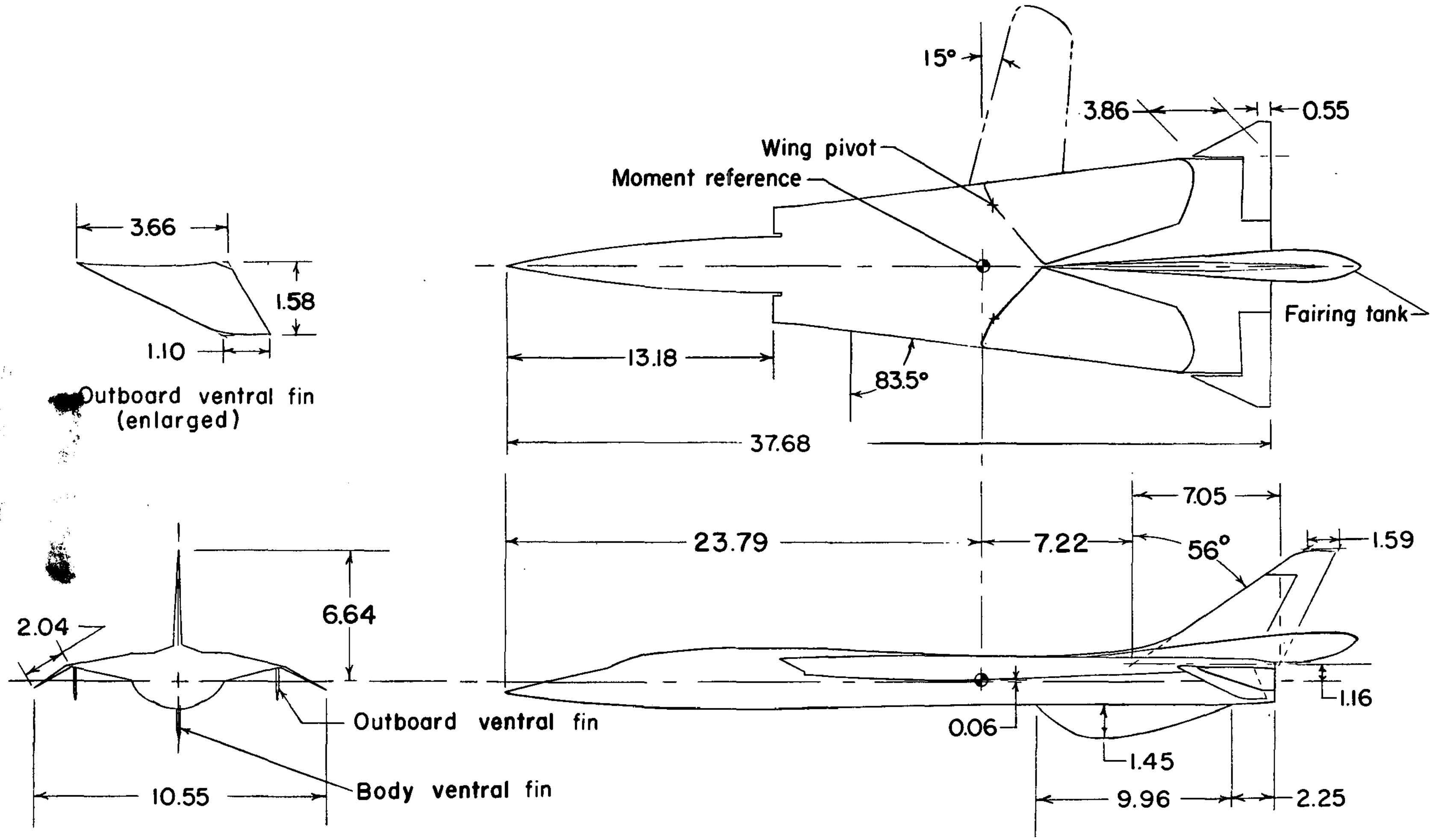


Figure 1.- Details of model with original vertical tail and ventral fins.

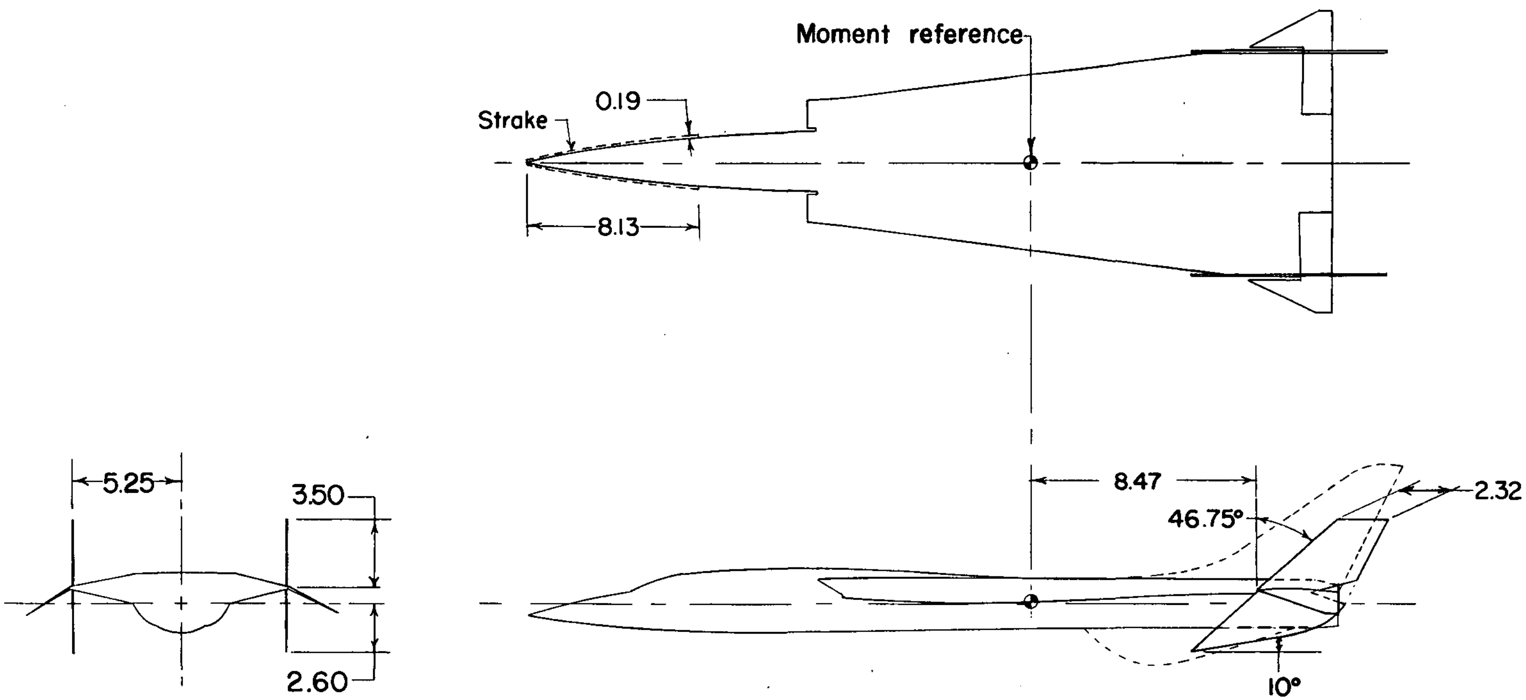
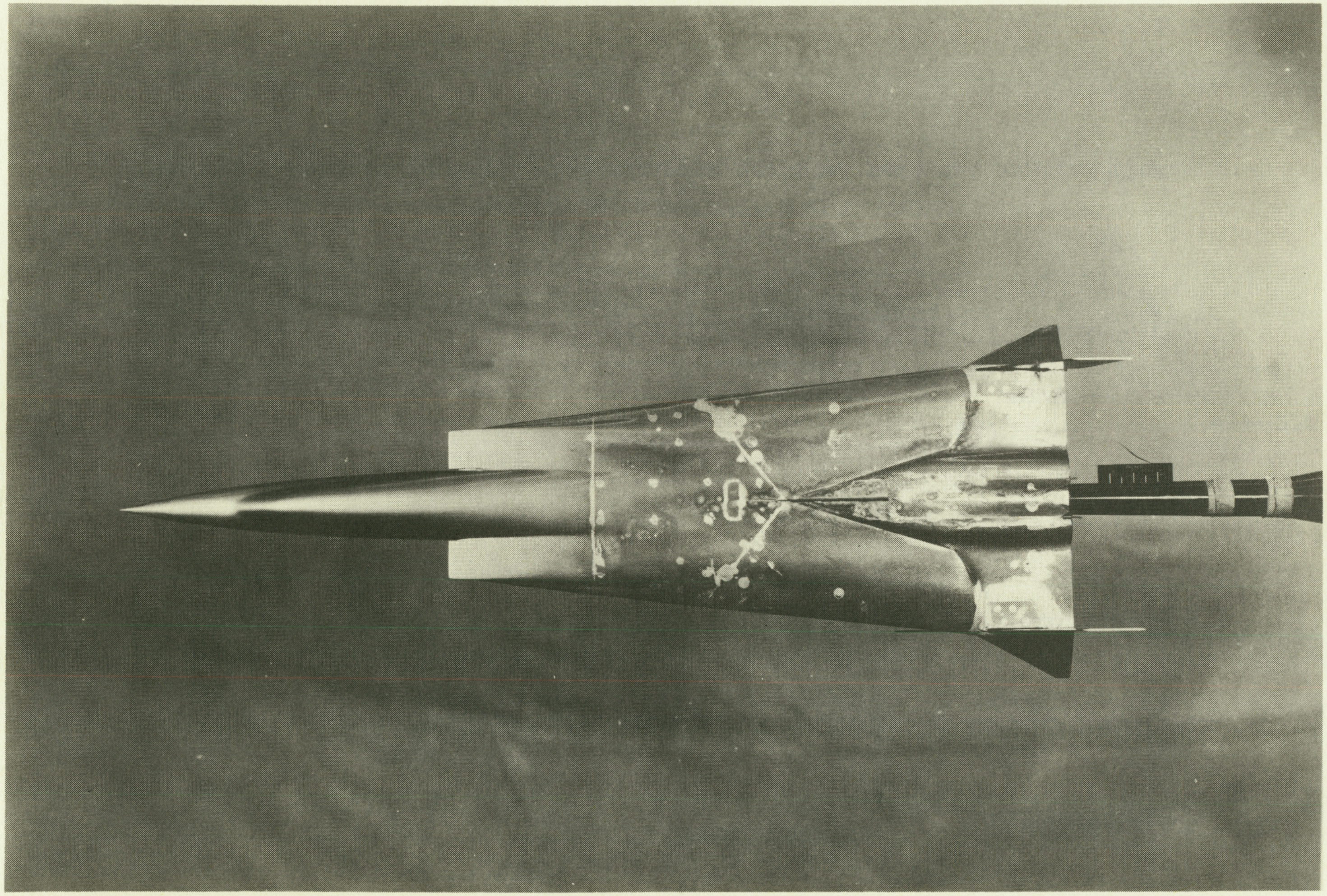


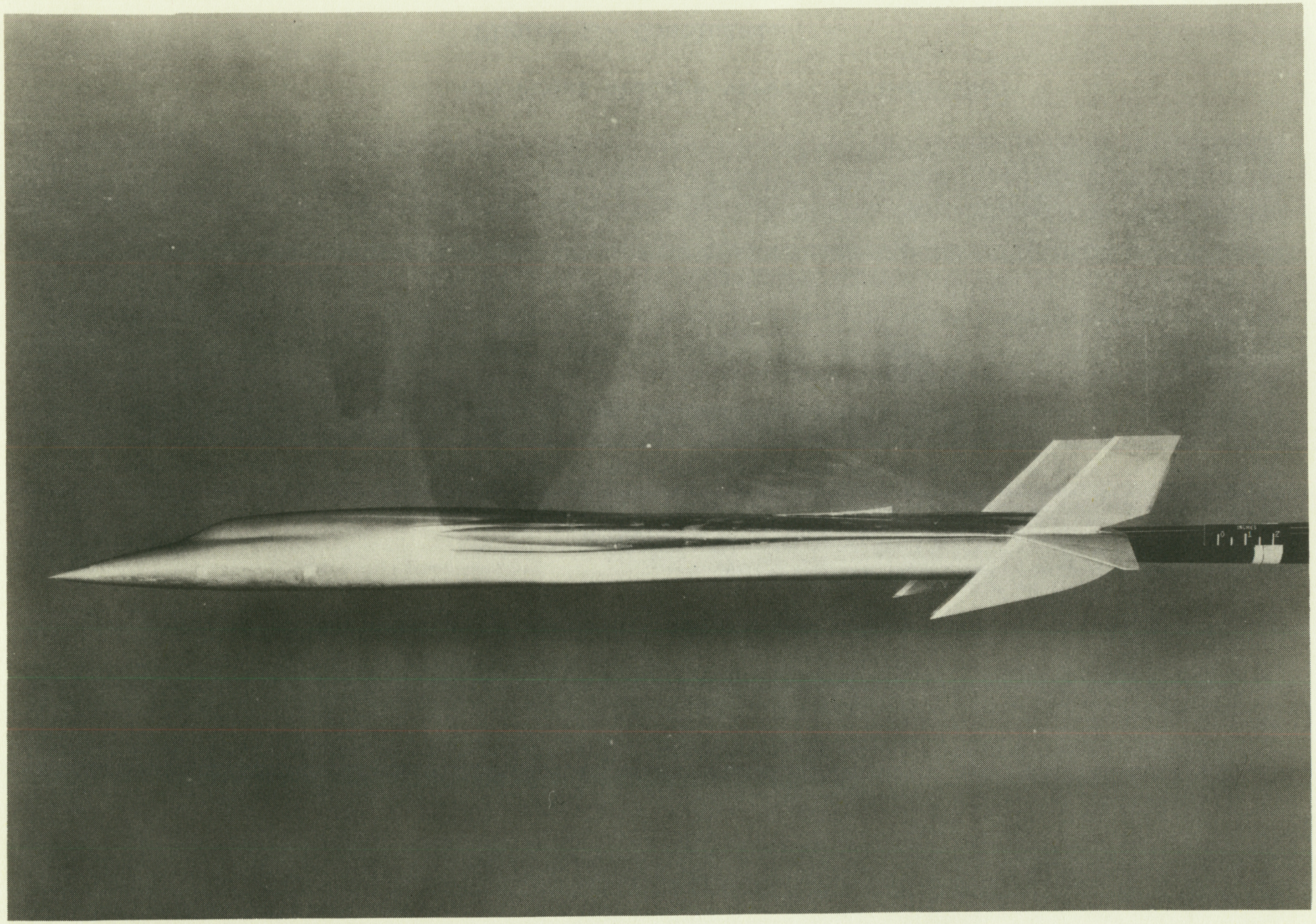
Figure 2.- Details of model with modified vertical tail and ventral fins.



(a) Top view.   L-61-2466

Figure 3.- Photographs of model.

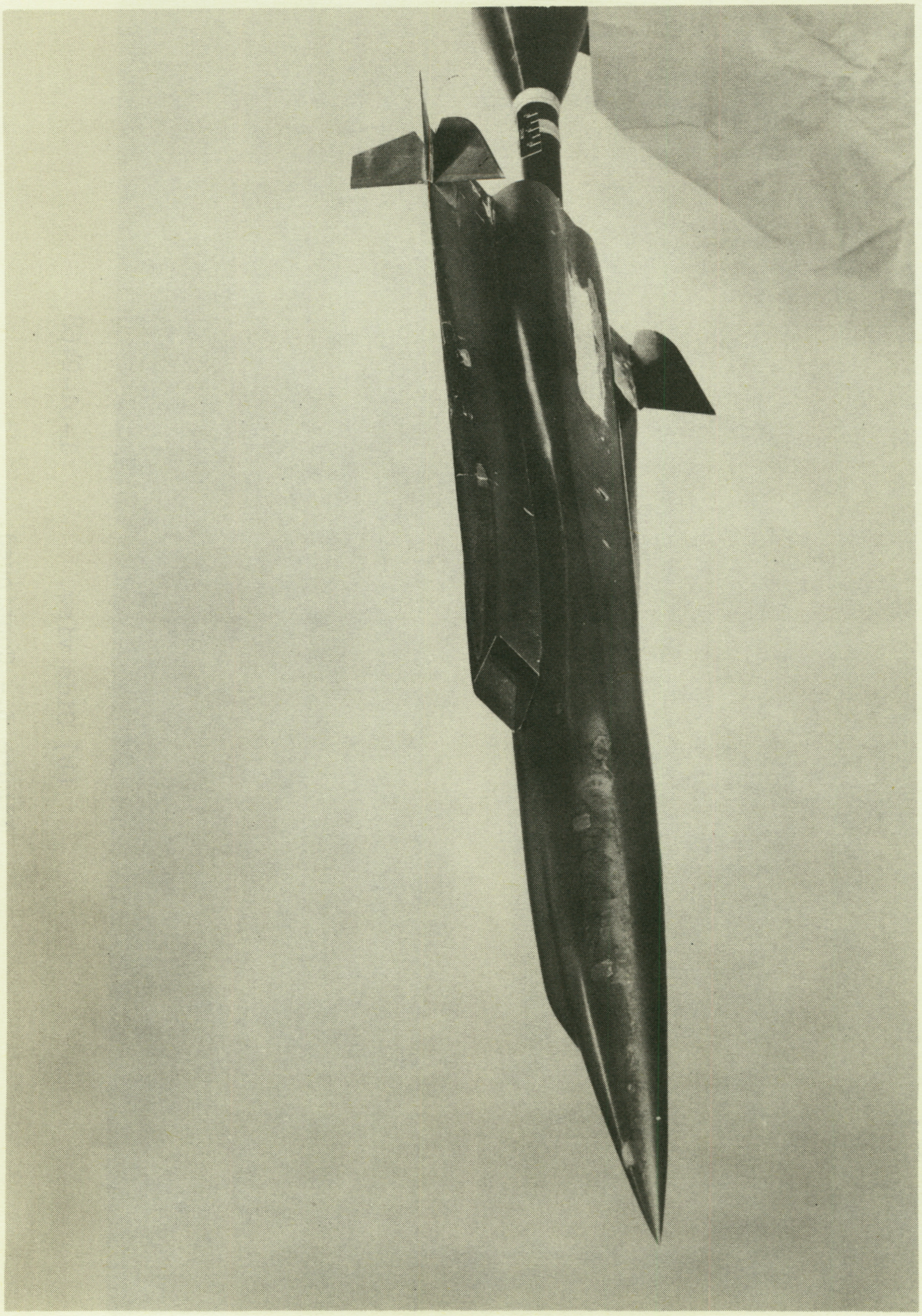
[redacted]



(b) Side view. L-61-2468

Figure 3.- Continued.

[redacted]



(c) Front oblique view. L-61-2467

Figure 3.- Concluded.

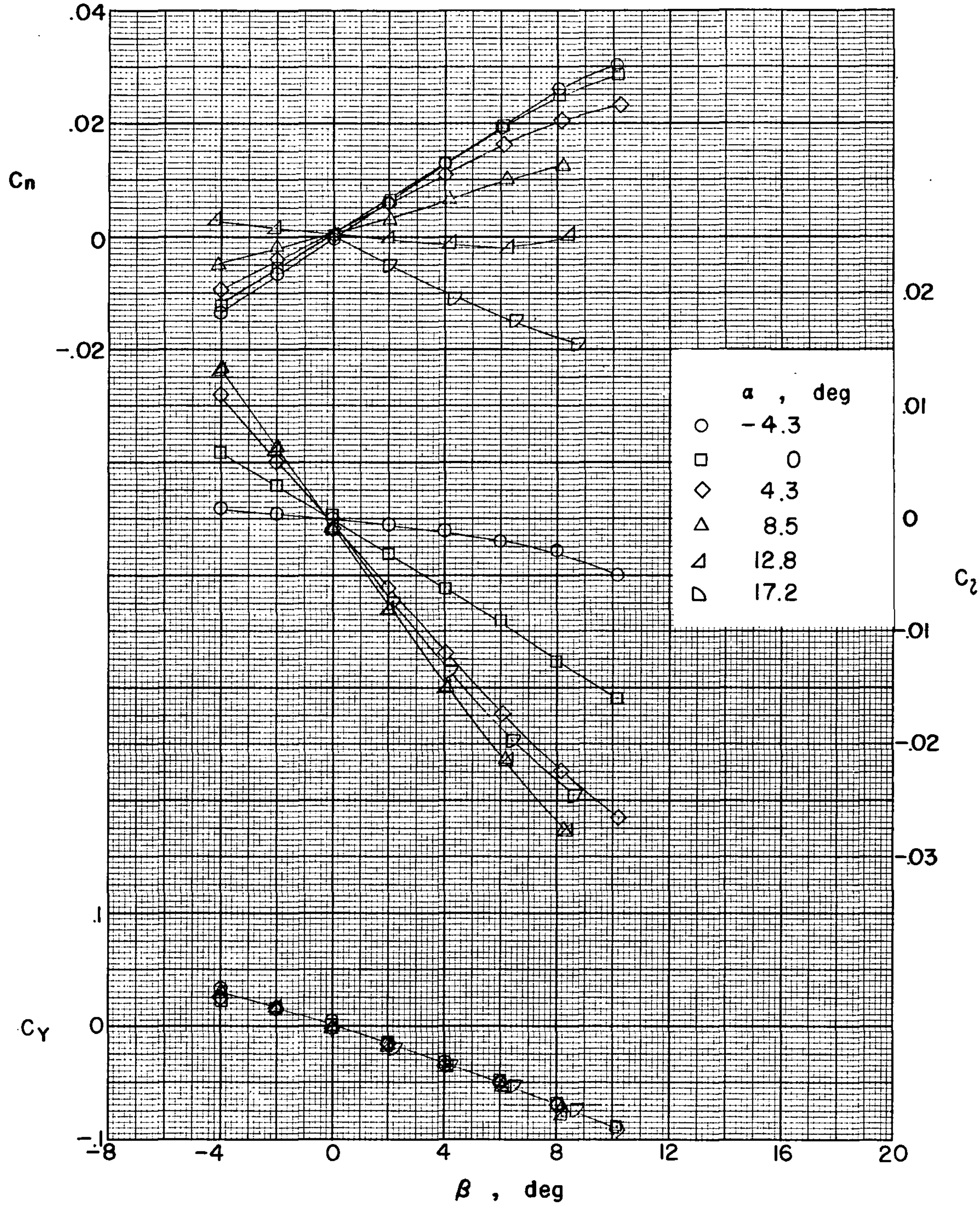


Figure 4.- Lateral aerodynamic characteristics in sideslip for configuration with original vertical-tail arrangement V_O.

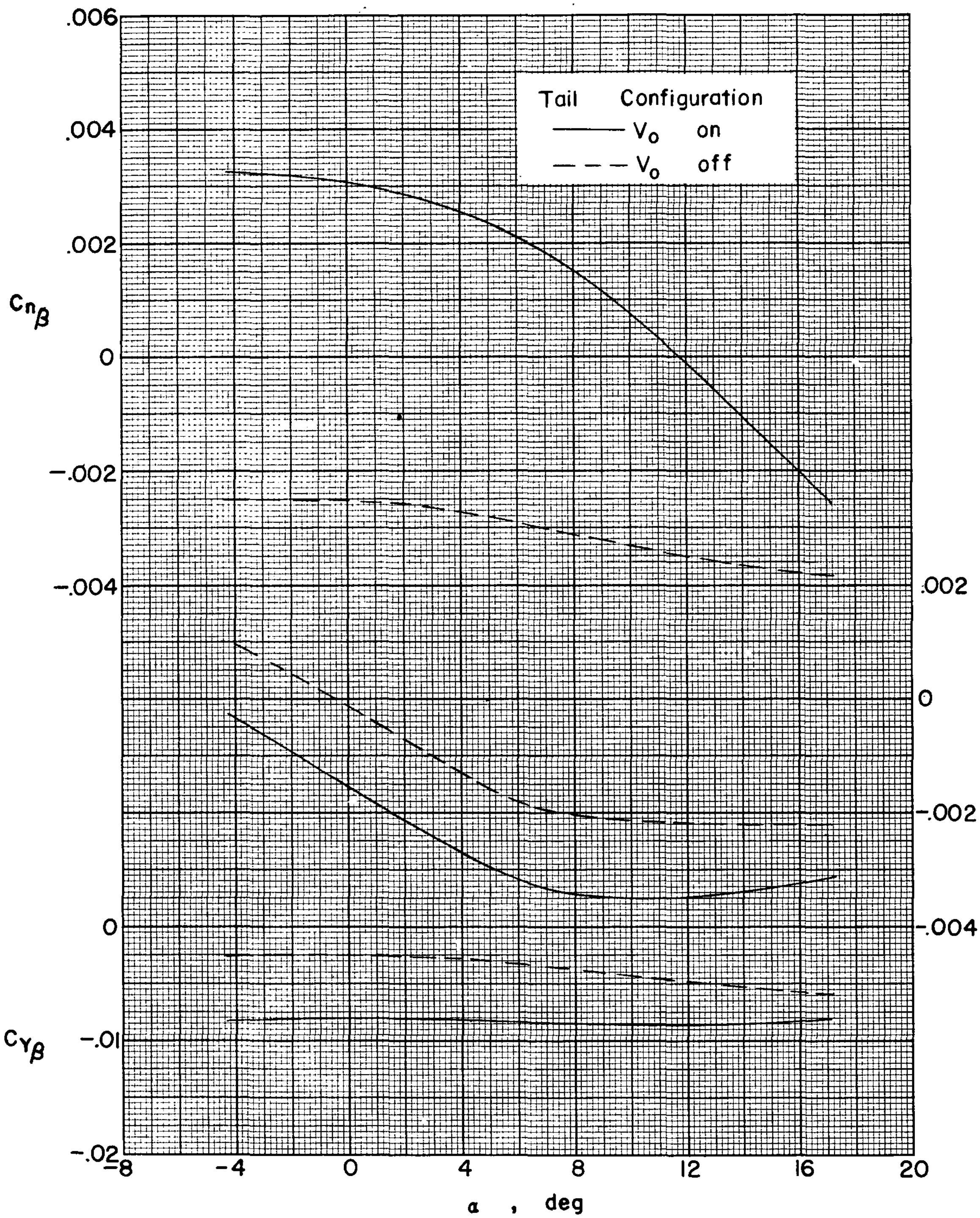


Figure 5.- Effect of original vertical tail on lateral stability derivatives of model in pitch.

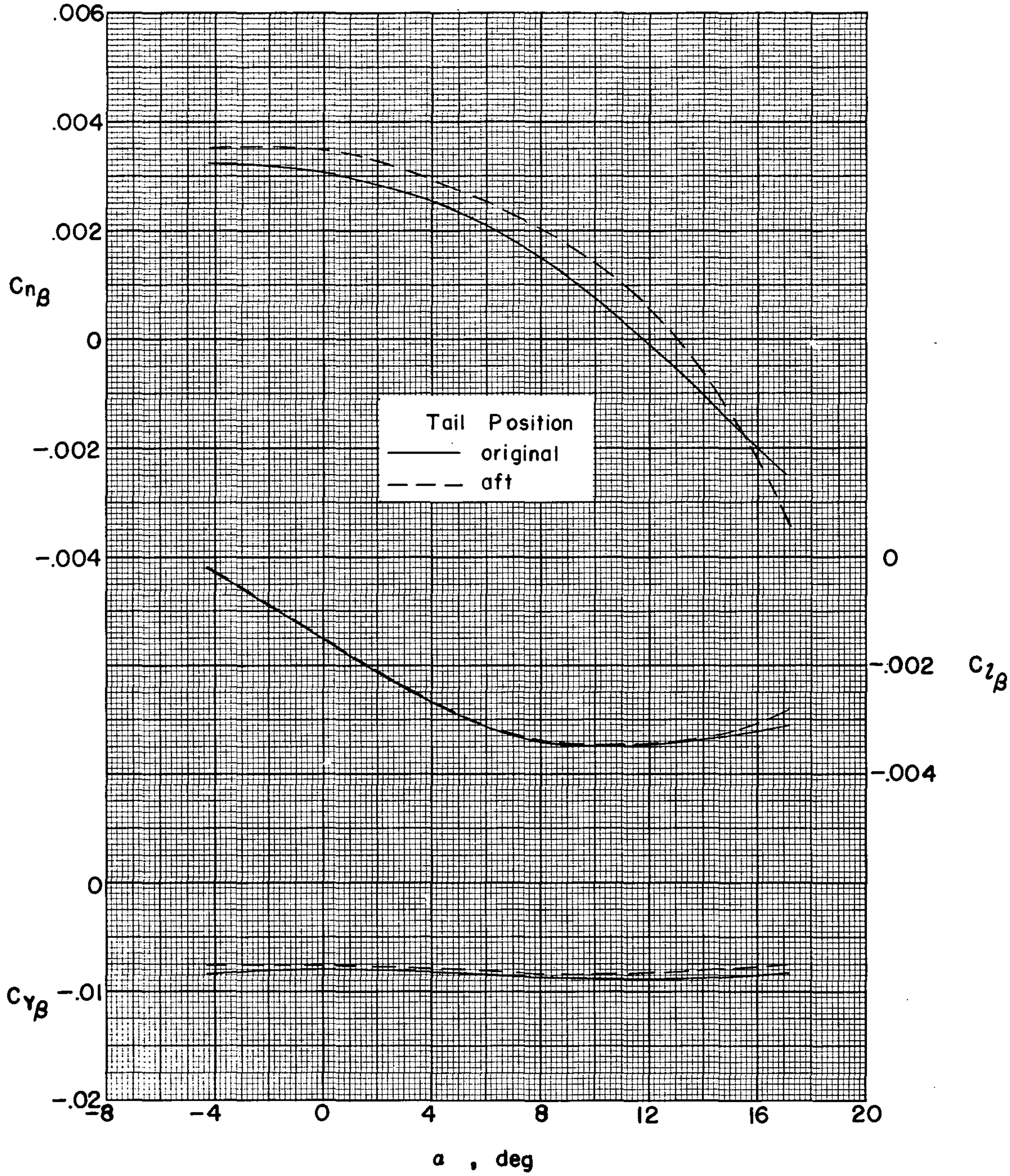


Figure 6.- Effect of rearward shift of original vertical tail on lateral stability derivatives of model in pitch.

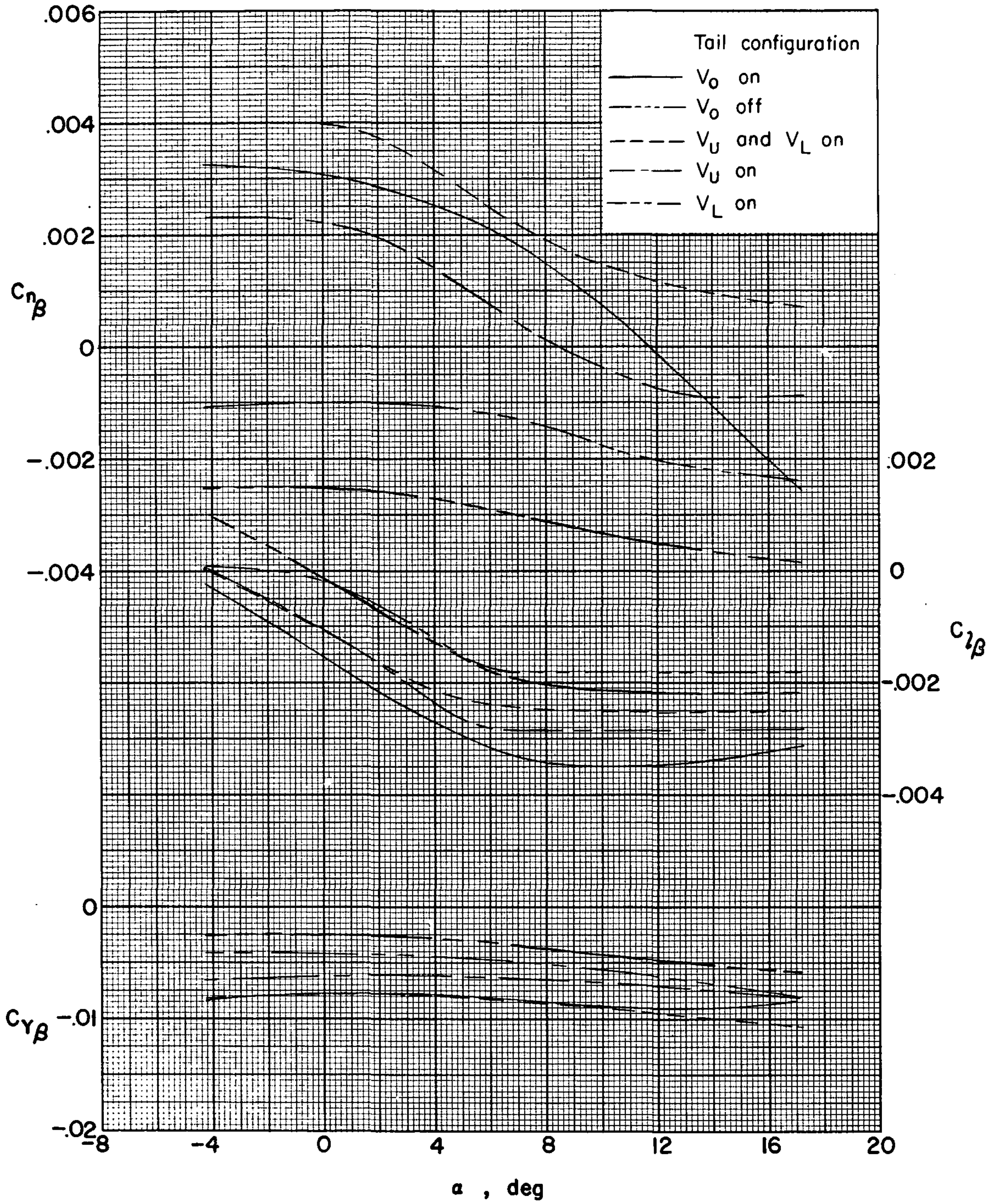


Figure 7.- Effects of original-tail and twin-vertical-tail arrangements on lateral stability derivatives of model in pitch.

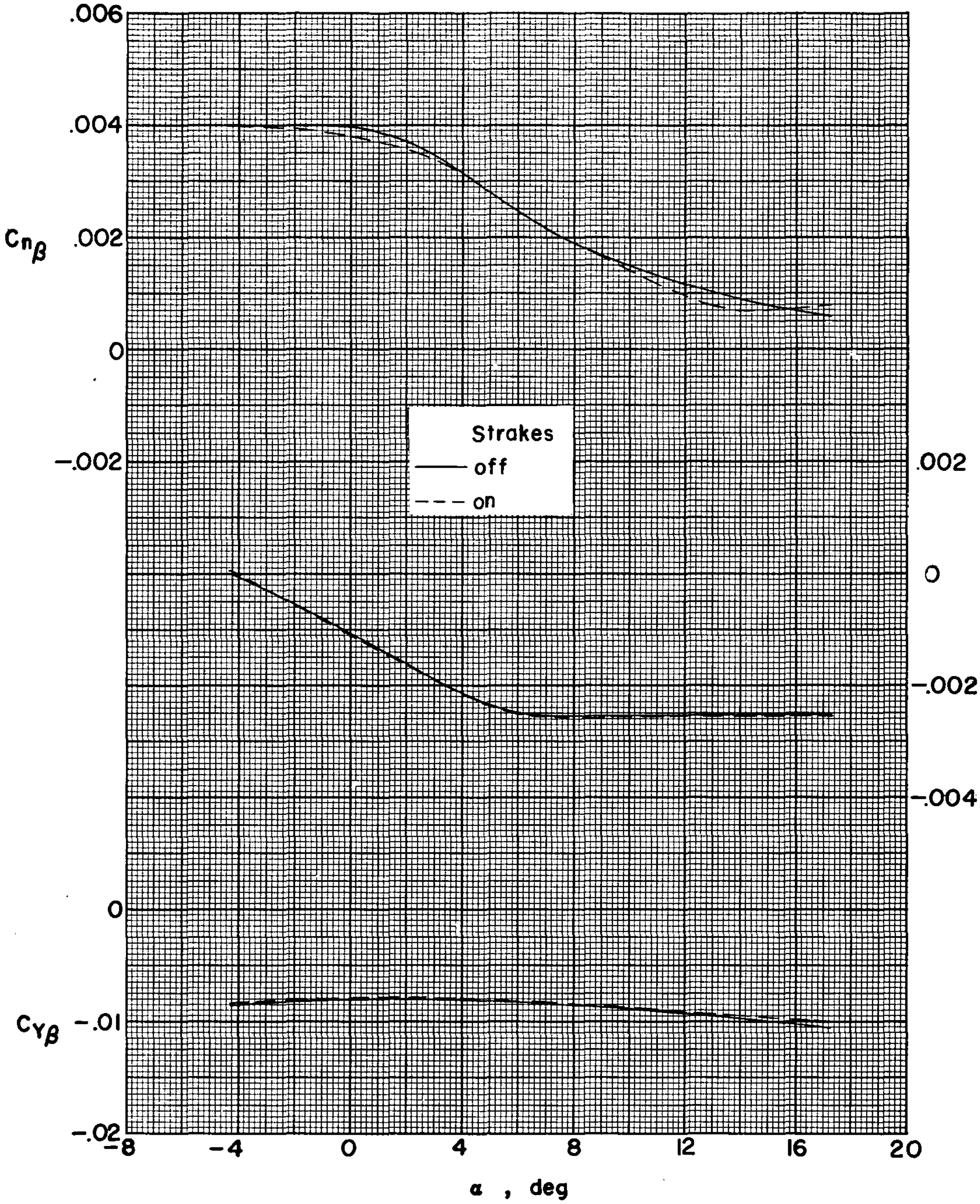


Figure 8.- Effects of body strakes on lateral stability derivatives of model in pitch with twin vertical tails in combination with twin ventral fins.

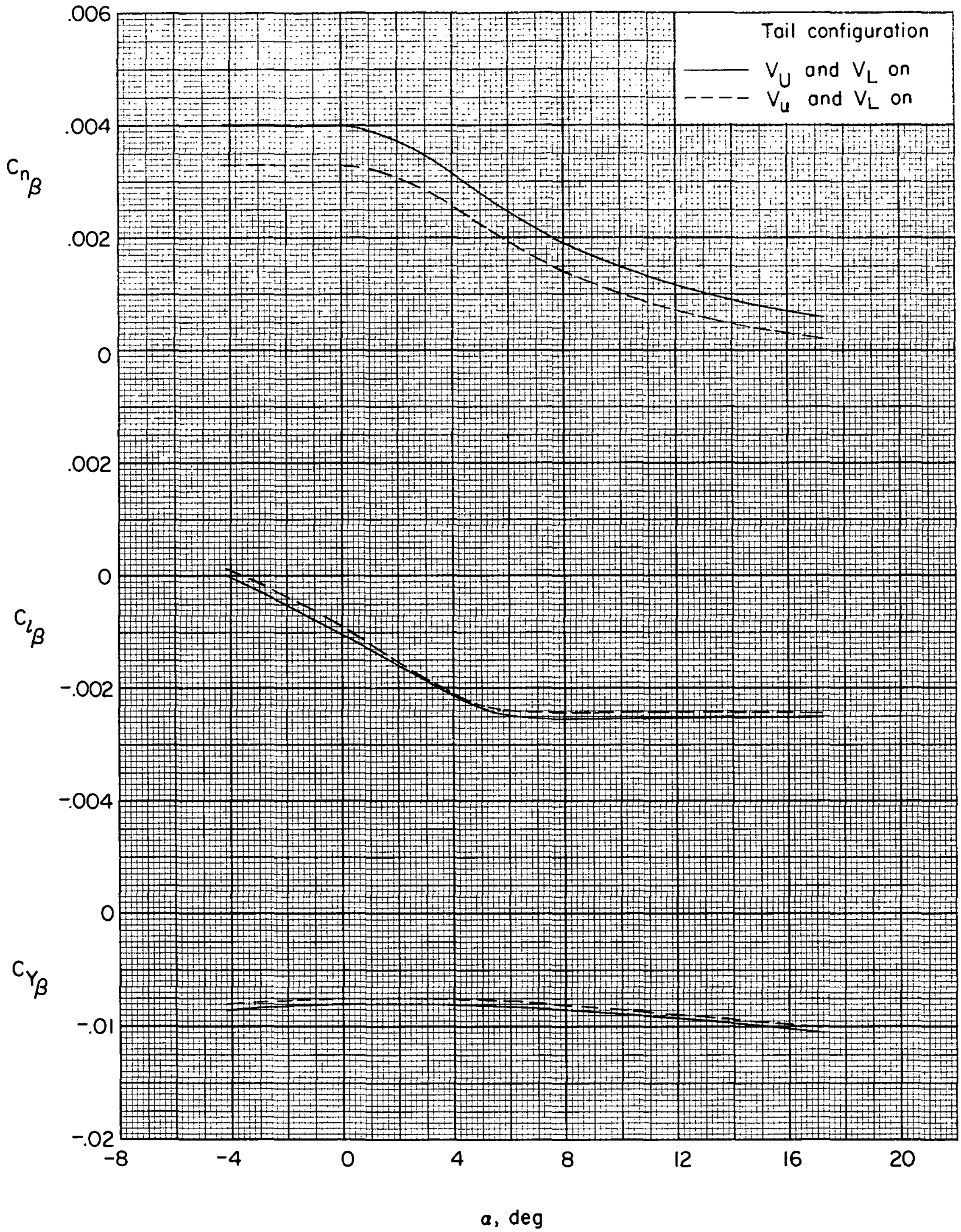


Figure 9.- Effect of decrease in span of upper component of twin vertical tails on lateral stability derivatives in pitch.

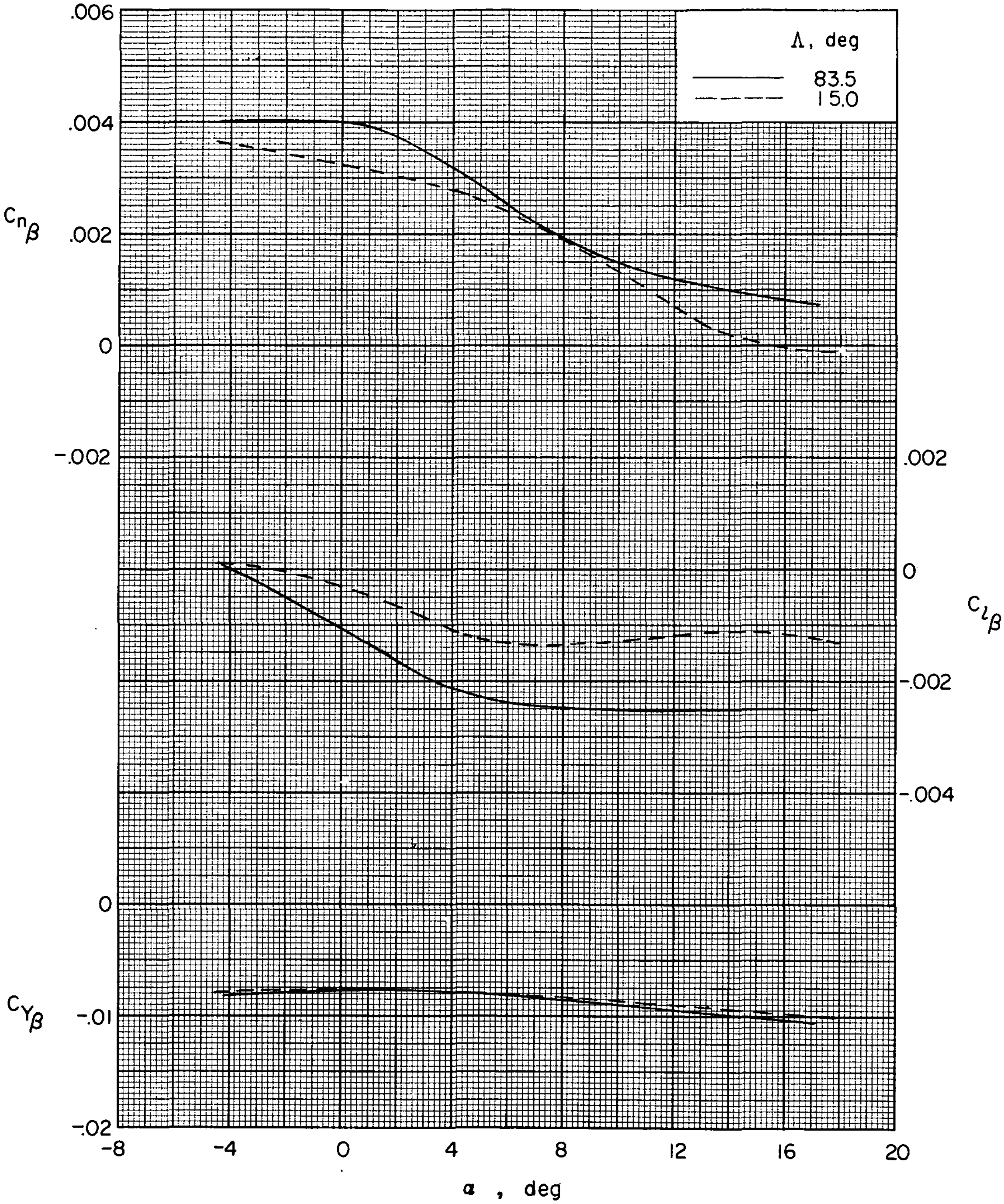


Figure 10.- Comparison of lateral stability derivatives of model with twin vertical tails and with wing outboard panels swept back 15° and 83.5°.

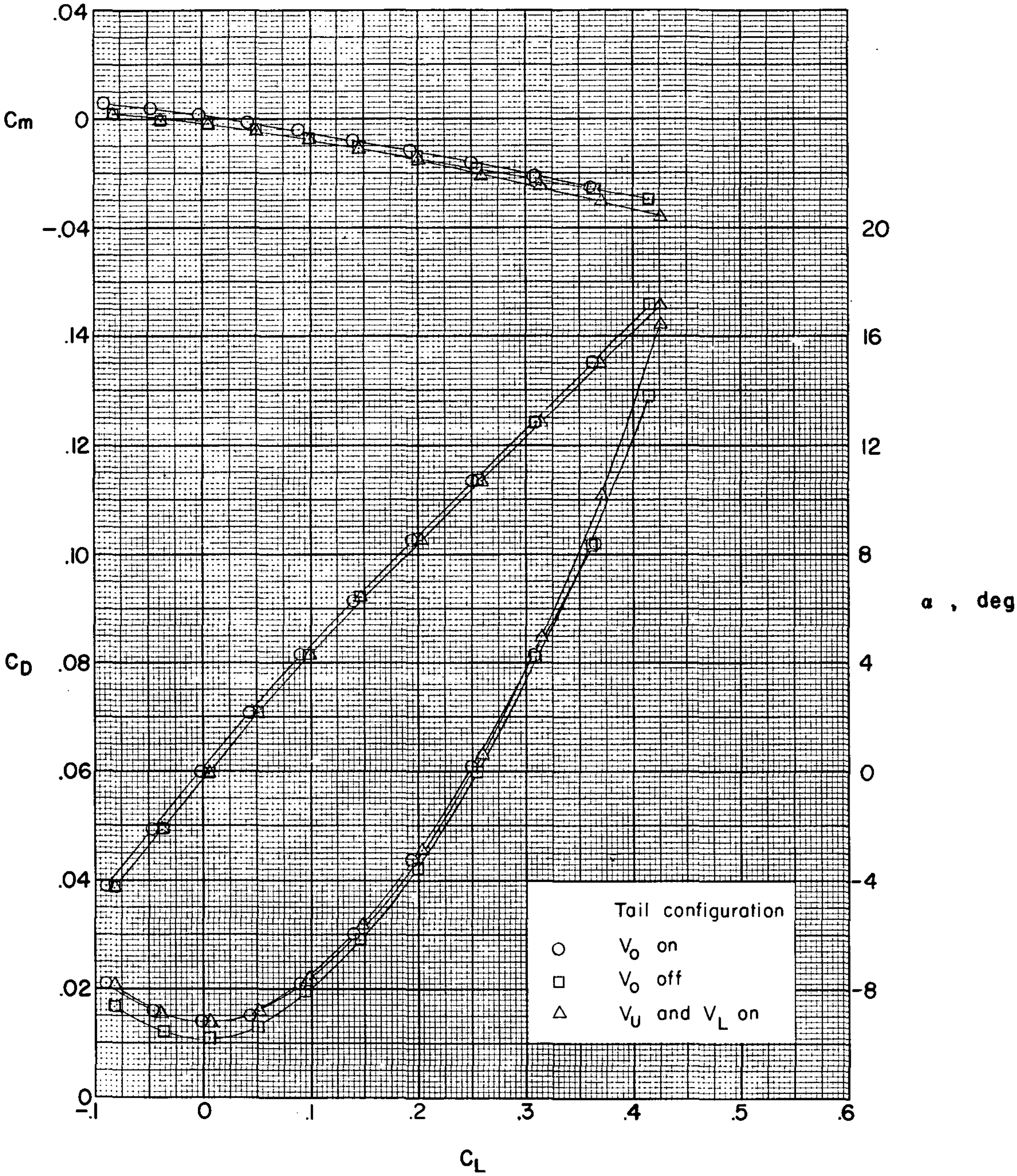


Figure 11.- Effects of original-vertical-tail and twin-vertical-tail arrangements on longitudinal aerodynamic characteristics of model with wings fully retracted. $\beta = 0^{\circ}$.